(12) UK Patent Application (19) GB (11) 2 294 227 (13) A

(43) Date of A Publication 24.04.1996

(21) Application No 9421076.2

(22) Date of Filing 19.10.1994

(71) Applicant(s)
Rover Group Limited

(Incorporated in the United Kingdom)

International House, Bickenhill Lane, Bickenhill, BIRMINGHAM, B37 7HQ, United Kingdom

Sulzer Metco (UK) Ltd
Westmead, Farnborough, Hampshire, GU14 7LP, United Kingdom

(72) Inventor(s)
Robert Andrew Dooley
David Ian Wimpenny

(74) Agent and/or Address for Service
Withers & Rogers
4 Dyer's Buildings, Holborn, LONDON, EC1N 2JT, United Kingdom

(51) INT CL[6]
B23P 15/24 , B22C 7/00 9/00 9/04 , B22D 23/00 , //
C23C 4/08 4/12 , C25D 1/00 1/20

(52) UK CL (Edition O)
B3F FCP F230
B3A A83A4 A83B7
C7B BCCK B112 B113 B325 B721
C7F FGA FP811 FP882 FP885 FQ851 FR885
U1S S1637 S1639 S1658

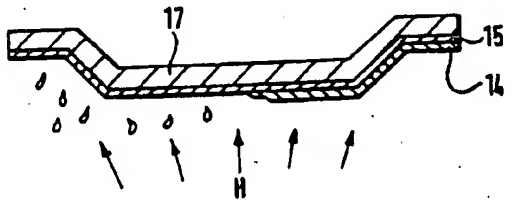
(56) Documents Cited
GB 1184095 A EP 0194172 A1 US 5268045 A
US 5079974 A US 4511438 A US 4231982 A
US 4088046 A US 2944338 A

(58) Field of Search
UK CL (Edition N) B3A , B3F FCP , B3G , B5A AT12A AT12P , C7B BBPA BCCK BDFA BDJA BGFA
INT CL[6] B22C 7/00 7/02 9/04 , B22D 23/00 , B23P 15/24 , B29C 41/08 , C25D 1/00 1/02 1/10 1/20
ONLINE DATABASES : WPI, CLAIMS

(54) The production of an article using a thermal spray technique

(57) The method comprises producing a former 14 of given shape from a thermal sprayed material, applying to the former 14 by thermal spraying a layer of material 15 having a melting point higher than that of the former 14, spraying a backing layer 17 on to the layer 15 and subsequently melting the former 14 from the layer 15 to produce the article. In a modification an article is produced by thermal spraying by the high velocity oxygen fuel (HVOF) technique and then providing a substantially rigid backing structure for the sprayed layer (Figs 12 - 14). Alternatively an article is produced by electroplating a metal layer on to a pattern of suitable shape, spraying a layer of material by an HVOF technique on to the electro-plated metal layer and removing the article so formed from the pattern.

FIG.4.



GB 2 294 227 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The print reflects an assignment of the application under the provisions of Section 30 of the Patents Act 1977.

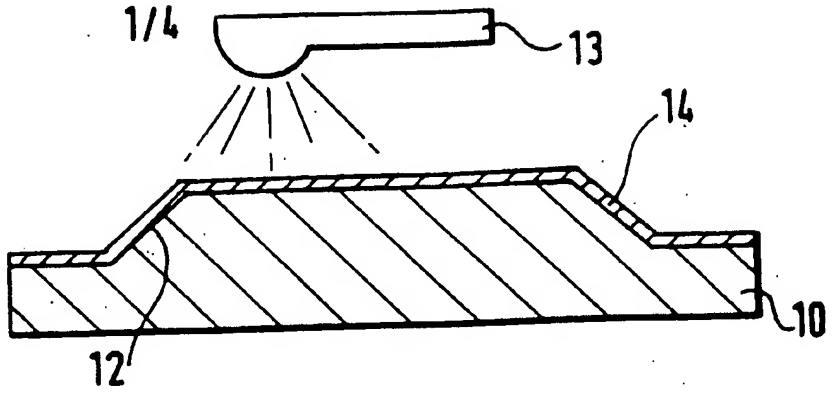


FIG.1.

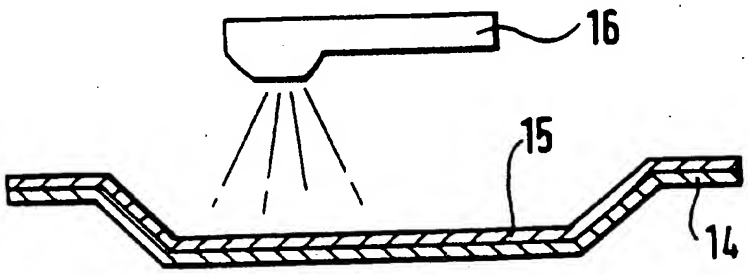


FIG.2.

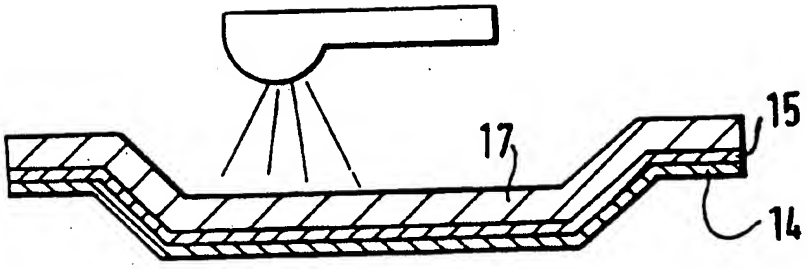


FIG.3.

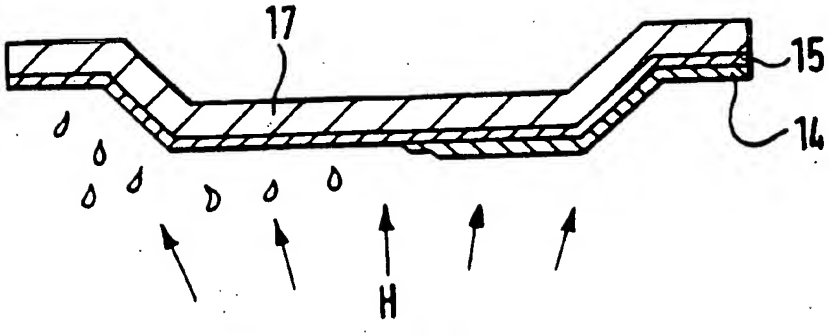


FIG.4.

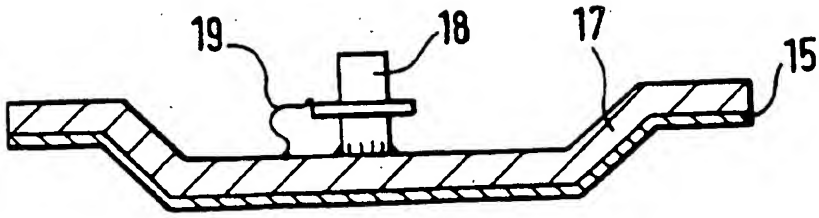


FIG.5.

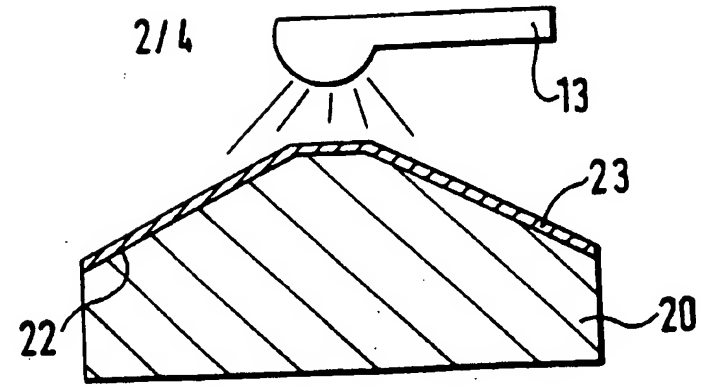


FIG.6.

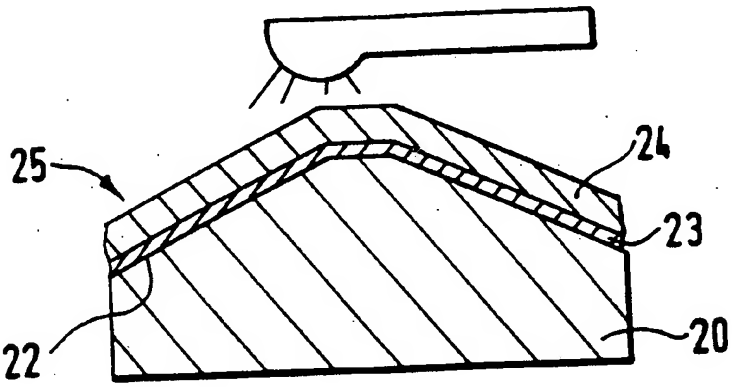


FIG.7.

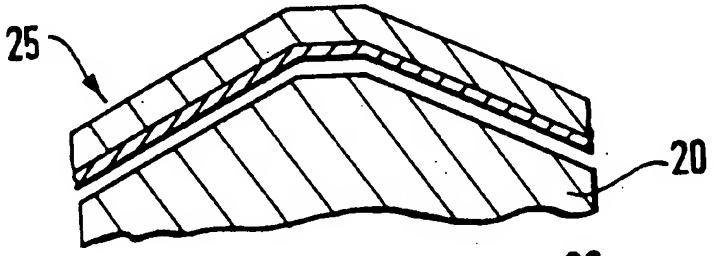


FIG.8.

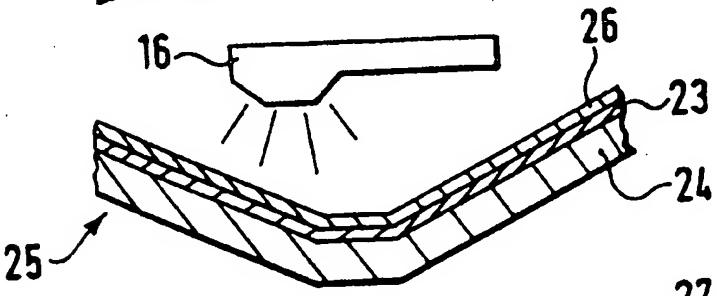


FIG.9.

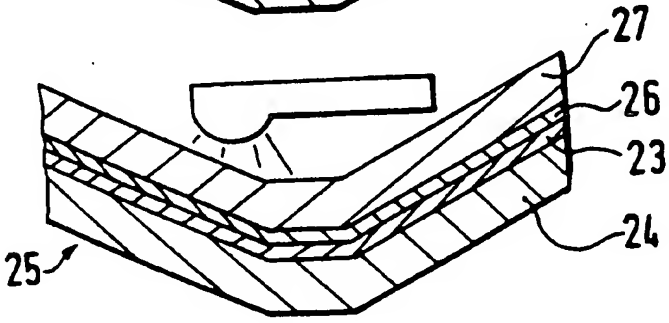


FIG.10.

FIG.11.

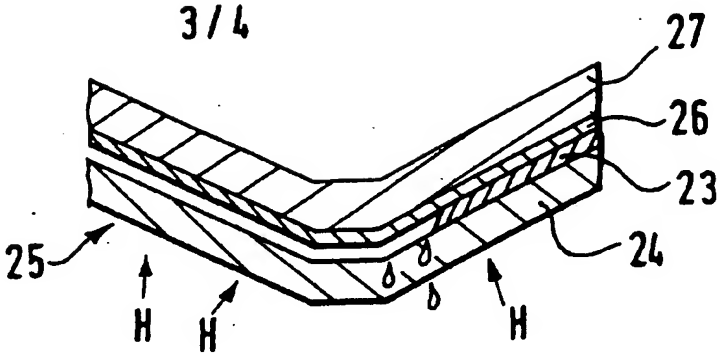


FIG.12.

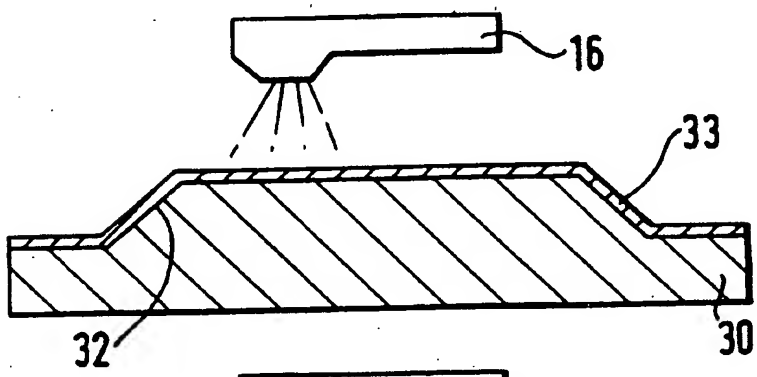


FIG.13.

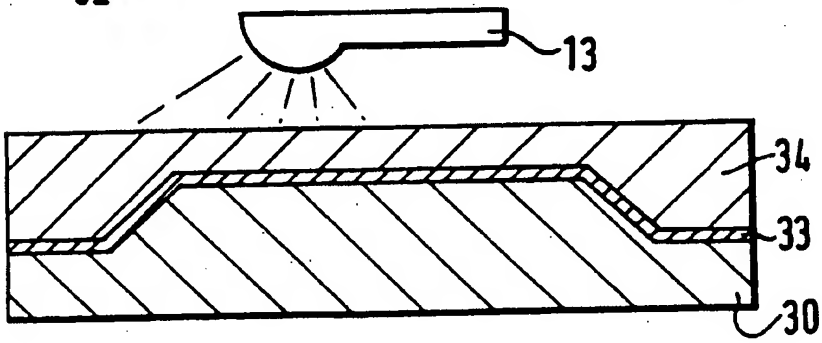


FIG.14.

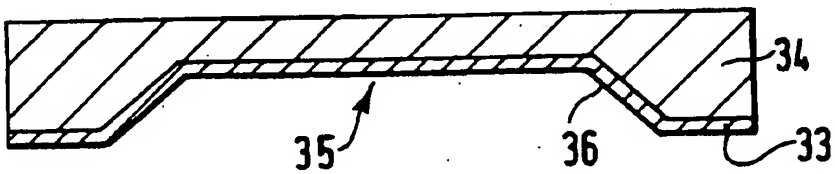
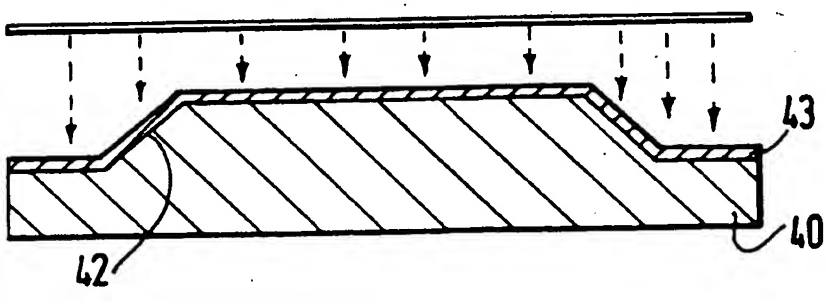


FIG.15.



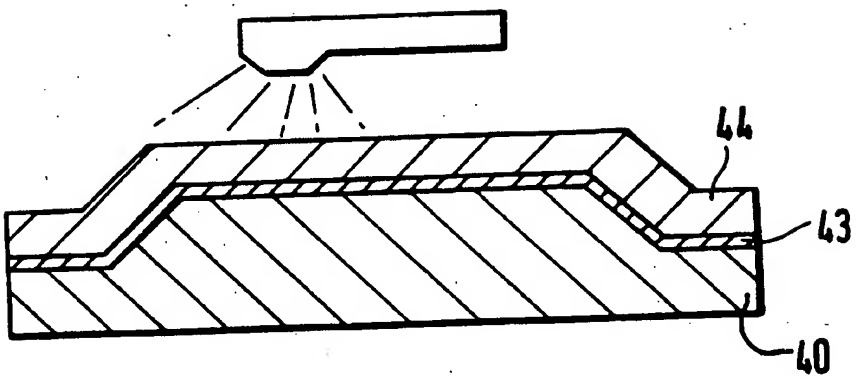


FIG.16.

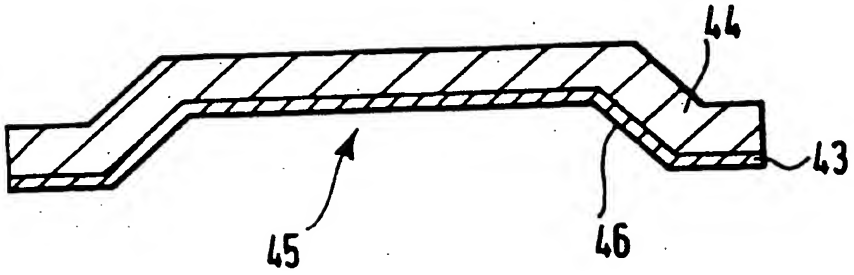


FIG.17.

THE PRODUCTION OF AN ARTICLE USING A THERMAL SPRAY TECHNIQUE

The invention relates to the production of an article using a thermal spray technique.

It has been known for many years to produce articles by thermal, eg metal, spraying and, in more recent times, it has been proposed to produce tooling having a working surface formed by thermal spraying.

One particular method of producing tooling by thermal spraying has involved producing a pattern having a surface shaped to provide the required shape of a tool, using a metal spraying technique to produce a hard, wear-resistant layer on the surface of the pattern, introducing on to the sprayed layer a suitable backing material to provide rigidity and then removing the sprayed layer from the pattern.

An object of the present invention is to provide an improved method of producing an article by a thermal spraying technique.

According to one aspect of the invention there is provided a method of producing an article by thermal spraying comprising producing a former of given shape by

thermal spraying a material on to a pattern, applying to the former by thermal spraying a layer of material having a melting point higher than that of the former and removing the former by melting from the layer.

With such a method, removal of the former from the thermal sprayed layer by melting minimises risk of damage to the thermal sprayed layer of material which is extremely useful where a face of the layer is to form a working surface of a tool.

Preferably, the method includes applying to the layer of material a layer of backing material to provide a substantially rigid backing structure for the first layer. In such a case, the layer of backing material is preferably applied to the layer of material prior to melting away the former.

The meltable material of the former may be a low melting point metal such as zinc or a zinc/tin alloy.

The backing layer may also be applied by thermal spraying and, in such a case, the sprayed material preferably has a melting point higher than that of the meltable material of the former. In that way, melting of the former will not cause melting of the backing material to occur.

Preferably, the layer of material sprayed on to the former is applied by an HVOF spray technique. The HVOF (high velocity oxygen fuel) technique utilises a fuel gas mixed with oxygen in a combustion chamber to provide a high temperature. The material to be sprayed is fed in into the combustion chamber so that rapid heating and acceleration of the material takes place. The material (powder or wire) is propelled in molten form from a nozzle by the gas at high velocity towards a target to be sprayed. The HVOF system propels the molten material at velocities which are normally higher than those used in other forms of thermal spraying techniques. It will be appreciated, however, that any other thermal spraying technique could be used. Also, it has been found that a layer applied by an HVOF technique is particularly useful where the layer has a face to be used as an electro discharge machining (EDM) electrode. If desired, a simultaneous spray deposition and peening (SSP) technique could be used to apply the layer of material to the former.

According to a second aspect of the invention there is provided a method of producing an article by thermal spraying comprising producing a layer of material of suitable surface shape by an HVOF technique and providing for the sprayed layer a substantially rigid backing structure.

As HVOF coatings have greater coating integrity combined with low thermal stresses than coatings provided by other thermal spraying techniques, the risk of damage to the sprayed layer if it is detached from a pattern is minimised and there is reduced risk of distortion during thermal contraction.

According to a third aspect of the invention there is provided a method of producing an article by thermal spraying comprising electro-plating a metal layer on to a pattern of suitable surface shape, spraying a layer of material by an HVOF technique on to the electro-plated metal layer and removing the article so formed from the pattern.

The HVOF applied coating provides additional mechanical strength to the electro-plated metal layer without significantly reducing the thermal or electrical conductivity where applicable.

The invention also includes an article such as a tool or EDM electrode made by a method according to any of the first, second or third aspects of the invention or in accordance with any of the consistory clauses relating thereto. Such a tool may have a working surface formed by the HVOF or electroplated layer. Where the article is an EDM electrode, it may have a working surface formed by

the HVOF or electroplated layer.

A method of producing an article in accordance with the invention will now be described by way of example with reference to the accompanying drawings in which:

Fig 1 is a diagrammatic cross-sectional view showing the spraying of a low melting point metal on to a pattern to produce a former,

Fig 2 is a view of the former in Fig 1 removed from a pattern, the former being inverted and a layer of material being sprayed thereon,

Fig 3 is a view similar to Fig 2 showing the spraying of a backing layer thereon,

Fig 4 is a cross-sectional view of the article formed in Fig 3 showing heat applied thereto so as to melt the former,

Fig 5 is a cross-sectional view of the article formed by the steps shown in Figs 1 to 4 with a stem attached thereto to enable the article to be used as an EDM electrode,

Fig 6 is a diagrammatic cross-sectional view showing the

spraying of a low melting point metal on to a pattern as in Fig 1,

Fig 7 is a view similar to Fig 6 showing a layer of material being sprayed on to the low melting paint material to complete production of a former,

Fig 8 shows the former produced in Fig 7 separated from the pattern,

Fig 9 is a view of the former of Fig 8 inverted and a layer of material being sprayed on to the low melting point material layer of the former,

Fig 10 is a view similar to Fig 9 showing the spraying of a layer of backing material,

Fig 11 is a cross-sectional view of the article formed in Fig 10 showing heat applied thereto so as to enable the former to be removed by melting,

Fig 12 is a diagrammatic cross-sectional view showing a pattern being coated by an HVOF technique,

Fig 13 is a cross-sectional view of the coating of Fig 12 receiving a backing layer,

Fig 14 is a cross-sectional view of the article formed by the steps of Figs 12 and 13 removed from the pattern,

Fig 15 is a cross-sectional view of a pattern having a surface thereof being electroplated,

Fig 16 is a cross-sectional view of the electroplated layer in Fig 15 having a layer of material applied thereto by an HVOF technique and

Fig 17 is a cross-sectional view of the article formed by the steps of Figs 15 and 16 removed from the pattern.

Looking at Fig 1, a pattern 10 has a surface 12 corresponding to the shape of an electro discharge machining (EDM) tool. An alloy of zinc and tin is applied by means of a metal spraying gun 13 to the surface 12 so as to produce a former 14 as a layer of material on the surface 12. Spraying is continued to build up the thickness of the former 14 to around 3 to 4 mm.

The former 14 is then removed from the pattern 10 and inverted as shown in Fig 2. A layer 15 of metal (in this case, copper) is then sprayed on to the upwardly facing surface of the former 14. The metal is sprayed using an HVOF system 16 as described hereinbefore to build up a

copper layer thickness of around 1 to 2 mm. It will be appreciated, of course, that a different thickness of material may be applied by the HVOF system 16. A suitable HVOF system is available from Metco Limited of Chobham, Woking, Surrey.

As shown in Fig 3, a backing material, in this case zinc, is applied by thermal spraying to form a backing layer 17 on the copper layer 15. The thickness of the backing layer 17 will be selected to provide the necessary degree of rigidity for the EDM tool.

Looking at Fig 4, heat H is then applied to the former 14, the temperature of the applied heat being sufficient to melt the former 14 away from the copper layer 15.

It will be noted that the melt temperature of the zinc/tin alloy used to produce the former 14 is around 270°C. The spray temperature of the HVOF applied copper is around 1082°C. However, because of the small mass of the sprayed particles, the zinc/tin material of the former 14 dissipates the heat and there is only microscopic surface melting of the former 14 on the side in contact with the copper. The spray temperature of the zinc backing layer 17 is around 420°C but, because of the small mass of the sprayed particles, the heat therefrom is dissipated through the copper layer 15 and the

material of the former 14.

Therefore, it will be appreciated that the melting point of the former 14 is less than the melt point of the backing layer 17 (which itself is less than the melt point of the intermediate copper layer 15) so that melting of the former as shown in Fig 4 has no effect on the backing layer.

A conductive stem 18 is then attached to the backing layer 17 and is suitably electrically connected to the backing layer, eg by a wire 19. The article made according to paragraphs 1 to 5 can then be used as an EDM electrode, the lower face of the copper layer 15 as viewed in Fig 5 forming the working surface of the electrode.

Whilst specific reference has been made in Figs 1 to 5 to the production of an EDM electrode, a method in accordance with the invention may be used to produce different types of tool, for example, a press tool. In such a case, instead of spraying copper using the HVOF system, a harder material such as chrome tool steel or a tungsten carbide containing material could be thermally sprayed on to a suitably shaped former 14 and a suitable backing layer subsequently applied before the former is melted away. The hard steel layer then defines a working

surface of the tool.

Instead of using an HVOF system to spray the metal layer 15, the layer could be sprayed by means of other thermal spray techniques including plasma spraying, detonation gun spraying or simultaneous spray peening. Apparatus describing simultaneous spray peening is described in UK-A-1 605 035 to which the reader is directed.

If desired the article could be produced by melting the former 14 after the Fig 2 step, the article then comprising the layer 15.

Figs 6 to 11 illustrate the way in which an article can be produced using a former which comprises a plurality of layers of different materials.

In Fig 6, a pattern 20 has a surface 22 thereof coated with a layer 23 of low melting point metal such as an alloy of zinc and tin. The metal layer 23 is applied by thermal spraying in the same way as the layer 14 in Fig 1. The layer 23 may be of any suitable thickness, eg around 3 to 4 mm.

As shown in Fig 7, another layer 24 of material, such as zinc, having a melt temperature higher than that of the low melting point layer 23 is applied by thermal spraying

to the low melting point metal layer 23 to provide rigidity to the layer 23. The combined layers 23, 24 provide a former generally indicated at 25.

The former 25 is then removed from the pattern 20 as shown in Fig 8 and is inverted as shown in Fig 9. A layer 26 of metal is then sprayed on to the upwardly facing surface of the low melting point layer 23 of the former 25. The layer 26 is applied preferably using an HVOF system 16 to build up a layer of desired thickness. The melt point of the material forming the layer 26 is higher than that of the low melting point layer 23 of the former 25.

As shown in Fig 10, a material such as zinc is applied by thermal spraying to form a backing layer 27 on the layer 26, the backing layer 27 providing a rigid backing structure of suitable thickness. The layer 26 will normally have a melt temperature greater than that of the layer 23 but less than that of the HVOF sprayed layer 26.

Heat H is then applied to the Fig. 10 multi-layer arrangement which causes the low melting point layer 23 to melt as shown in Fig 11 thereby leaving the article made from the layers 26,27.

The article can be used, for example, as a tool or an EDM

electrode. In each case, the working surface thereof will be defined by the HVOF applied layer 26.

The use of a former 25 including a further layer 24 enables a very low melting point material to be used for the layer 23. In that way, enhanced surface definition on the layer 23 at the interface with the pattern 20 can be achieved. That, in turn, will lead to enhanced transfer of the surface formation to the HVOF sprayed layer 26. The provision of the layer 24 reinforces the low melting point layer 23 to prevent or minimise distortion of that layer.

Reference is now made to Figs 12 to 17 which illustrate further methods in accordance with the present invention.

Referring to Fig 12, a pattern 30 has a surface 32 thereof coated with a layer of metal 33 applied by the HVOF system 16. Subsequently, a backing layer 34 is applied to the layer 33. The layer 34 may be of any suitable material but, in the embodiment shown in Fig 13, is a layer of metal applied by a metal spray system 13. As shown in Fig 14, the completed article indicated at 35 is removed from the pattern 30. The article 35 defines a cavity 36 having a face formed by the HVOF sprayed layer 33. The layer 33 can, for example, be a layer of tool steel enabling the article to be used, say, as a press tool having a working surface defined by the layer

33.

The thickness of the HVOF sprayed layer 33 may be around 1 mm and the layer of material 34 can be of any desired thickness to provide the necessary degree of rigidity to the article.

Referring to Figs 15 to 17, a pattern 40 has a surface 42 having a layer of metal 43 electroplated thereon. The electroplated material may be copper having a thickness in a range of around 0.1mm to 1mm. A layer of material 44 is then applied to electroplated layer 43 by means of an HVOF system 16. The layer 44 provides a rigid backing for the electroplated layer 43 and has a thickness of around 1 to 2mm. The material 44 may be a metal such as copper or zinc or other material such as a ceramic to provide the desired degree of rigidity to the final article. The article generally indicated at 45 in Fig 17 is then removed from the pattern 40 for subsequent use. The article 45 may comprise a tool having a cavity 46, the cavity having a working surface defined by the electroplated layer 43.

The methods according to the invention are especially useful in the field of rapid prototyping particularly for the production of tooling and EDM electrodes.

CLAIMS

1. A method of producing an article by thermal spraying comprising producing a former of given shape by thermal spraying a material on to a pattern, applying to the former by thermal spraying a layer of material having a melting point higher than that of the former and removing the former by melting from the layer.

2. A method according to Claim 1 including applying to the layer of material a layer of backing material to provide a substantially rigid backing structure for the first said layer.

3. A method according to according to Claim 2 including applying the layer of backing material to the first layer of material prior to melting away the former.

4. A method according to according to Claim 2 or 3 including applying the layer of backing material by thermal spraying.

5. A method according to according to Claim 4 including selecting a backing material having a melting point higher than that required to melt the former from the first said layer.

6. A method according to according to Claim 5 in which the melting point of the backing material is less than that of the first said layer.

7. A method according to according to any preceding Claim including producing at least part of the former from a low melting point metal or metal alloy.

8. A method according to any preceding claim including spraying the layer of material on to the former by an HVOF spray technique.

9. A method according to any preceding claim including producing the former from a plurality of layers of different materials applied by thermal spraying.

10. A method according to Claim 9 in which at least one of the layers is formed from a low melting point material to enable the former to be removed by melting.

11. A method of producing an article by thermal spraying substantially as described herein with reference to Figs 1 to 5 or Figs 6 to 11 of the accompanying drawings.

12. An article formed by a method according to any preceding Claim.

13. An article according to Claim 12 in the form of a tool, the tool having a working surface defined by the layer of material sprayed on to the former and from which the former has been melted.

14. An article according to Claim 12 in the form of an electro discharge machining (EDM) electrode having a

working surface defined by the layer of material sprayed on to the former and from which the former has been melted.

15. A method of producing an article by thermal spraying comprising producing a layer of material of suitable surface shape by an HVOF technique and providing for the sprayed layer a substantially rigid backing structure.

16. A method of producing an article by thermal spraying comprising electro-plating a metal layer on to a pattern of suitable surface shape, spraying a layer of material by an HVOF technique on to the electro-plated metal layer and removing the article so formed from the pattern.

17. A method according to Claim 16 in which the pattern is formed by thermal spraying.

18. A method of producing an article by thermal spraying substantially as described herein with reference to Figs 12 to 14 or Figs 15 to 17 of the accompanying drawings.

19. An article made by a method according to Claim 15, 16, 17 or 18.

20. An article according to Claim 19 when appendant to Claim 15 in the form of a tool having a working surface formed by the HVOF layer.

21. An article according to Claim 19 when appendant to

Claim 16 or 17 in the form of a tool having a working surface formed by the electroplated layer.

22. An article according to Claim 19 when appendant to Claim 15 in the form of an electro discharge machining (EDM) electrode having a working surface formed by the HVOF layer.

23. An article according to Claim 19 when appendant to Claim 16 or 17 in the form of an electro discharge machining (EDM) electrode having a working surface formed by the electroplated layer.

Patents Act 1977 Examiner's report to the Comptroller under Section 17 (..e Search report)	Application number GB 9421076.2
Relevant Technical Fields (i) UK Cl (Ed.M) B3F (FCP); B3G; B3A; B5A (AT12P, AT12A) (ii) Int Cl (Ed.5) B22D 23/00; B22C (7/00, 7/02, 9/04); B23P 15/24; B29C (41/08)	Search Examiner P G BEDDOE Date of completion of Search 18 NOVEMBER 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASES: WPI, CLAIMS	Documents considered relevant following a search in respect of Claims :- 1-14

Categories of documents

X:	Document indicating lack of novelty or of inventive step.	**P:**	Document published on or after the declared priority date but before the filing date of the present application.
Y:	Document indicating lack of inventive step if combined with one or more other documents of the same category.	**E:**	Patent document published on or after, but with priority date earlier than, the filing date of the present application.
A:	Document indicating technological background and/or state of the art.	**&:**	Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 1184095	(CHELTON) see especially Claim 1; page 2 lines 40-85	1, 2, 14
X	US 5079974	(CARNEGIE) see especially Claim 1; column 2 line 64 - column 3 line 18 and Figures 1A-1E	1, 2, 14

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Jo (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

Patents Act 1977 SECOND SEARCH 19 Examiner's report to the Comptroller under Section 17 (The Search report)	Application number GB 9421076.2
Relevant Technical Fields (i) UK Cl (Ed.N) B3F (FCP); B3G; B3A (ii) Int Cl (Ed.6) B22D 23/00; B22C (7/00, 7/02, 9/04); B23P 15/24	Search Examiner P G BEDDOE Date of completion of Search 14 JUNE 1995
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE: WPI, CLAIMS	Documents considered relevant following a search in respect of Claims :- 15 and in part 18, 19, 20, 22

Categories of documents

X:	Document indicating lack of novelty or of inventive step.	P:	Document published on or after the declared priority date but before the filing date of the present application.
Y:	Document indicating lack of inventive step if combined with one or more other documents of the same category.	E:	Patent document published on or after, but with priority date earlier than, the filing date of the present application.
A:	Document indicating technological background and/or state of the art.	&:	Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
Y	GB 1184095	(CHELTON) see especially Claim 1; page 2 lines 40-85	15,19
Y	US 5268045	(CLARE) see especially column 19 lines 23-31	15, 19
Y	US 4231982	(VOLVO) see especially column 2 lines 35-48	15, 19
Y	US 4088046	(HRB TOOLING) see especially Claim 1; column 10 lines 27-32; Figures	15, 19
Y	US 2944338	(GEC) see especially Claim 1; column 3 lines 25-51 and Figures	15, 19

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

20

Patents Act 1977 THIRD SEARCH
Examiner's report to the Comptroller under Section 17
(The Search report)

Application number
GB 9421076.2

Relevant Technical Fields

(i) UK Cl (Ed.N) B3F (FCP); B3G; B3A; C7B (BBPA, BCCK, BDJA, BDFA, BGFA)

(ii) Int Cl (Ed.6) B22D 23/00; B22C (7/00, 7/02, 9/04); B23P 15/24; C25D (1/00, 1/02, 1/10, 1/20)

Search Examiner
P G BEDDOE

Date of completion of Search
14 JUNE 1995

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ONLINE: WPI, CLAIMS

Documents considered relevant following a search in respect of Claims :-
16, 17 in part 18, 19; 21, 23

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
A	EP 0194172 A1	(LANGEVIN) see especialy Claim 1 and Figure 2	16, 19
X	US 4511438	(HARRIS) see especially Claim 1; column 3-7; Figure 2	

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journ (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).